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The Cathedral and the Bazaar: Monocentric and Polycentric River Basin Management

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ABSTRACT: Two contemporary theories of river basin management are compared. One is centralised 'regulatory river basin management' with an apex authority that seeks hydrometric data and nationally agreed standards and procedures in decisions over water quality and allocation. This model is commonplace and can be identified in many water training curricula and derivatives of basin management policy. The other, 'polycentric river basin management', is institutionally, organisationally and geographically more decentralised, emphasising local, collective ownership and reference to locally agreed standards. The polycentric model is constructed from the creation of appropriate managerial subunits within river basins. This model emphasises the deployment of hydrologists, scientists and other service providers as mediating agents of environmental and institutional transformation, tackling issues arising within and between the basin subunits such as water allocation and distribution, productivity improvement and conflict resolution. Significantly, it considers water allocation between subunits rather than between sectors and to do this promulgates an experimental, step-wise pragmatic approach, building on local ideas to make tangible progress in basins where data monitoring is limited, basin office resources are constrained and regulatory planning has stalled. To explore these issues, the paper employs the 'Cathedral and Bazaar' metaphor of Eric Raymond. The discussion is informed by observations from Tanzania, Nigeria and the UK.

KEYWORDS: Adaptive management, IWRM, regulatory water management, river basin management, sub-Saharan Africa

INTRODUCTION

In attempting to achieve pressing priorities of equitable and sustainable water management, countries across sub-Saharan Africa (SSA) are instituting reforms with the support of governments and the international donor community. Under the banner of Integrated Water Resources Management (IWRM) these reforms applied to the river basin emphasise statutory laws and formal institutional frameworks to regulate the use of water resources (IWMI et al., 2004; Jones and van der Walt, 2004; Kabudi, 2005; Sokile et al., 2005; Pitman, 2002). The reforms, underpinned by the Dublin Principles, translate into an operational reality of resource ownership vested in the state with varying levels of stakeholder participation and subsidiarity in water use decisions. Although academics hold mixed views regarding IWRM and river basin management, both are guiding philosophies of the international donor community's approach to water (European Commission, 1998; EU, 2005; Bonn Secretariat, 2001; World Bank, 2004). The Global Water Partnership (GWP, 2000) provides a generally accepted definition of IWRM as being a process that "… maximises the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". IWRM is a response to the interconnectedness of the water cycle at the catchment and aquifer scale, requiring that the full range of water users, their needs and impacts be considered together at both a policy and practice level in order to achieve equitable, efficient and sustainable water use.

Although IWRM is being rolled out to many developing countries its application in the field is coming under increasing review. This concern was part of the 2006 World Water Forum (GWP, 2006), and has been discussed by various authors (e.g. Biswas, 2004; Shah et al., 2005; Warner et al., 2008; Wester et al., 2009; Molle, 2009a). Adaptive Water Resources Management (AWRM) is one emerging response to these concerns, as evidenced by current literature and symposia (e.g. CAIWA, 2007). However, the adaptive water management literature is agnostic about, or supportive of, the regulatory approach, choosing instead to promote its application via iterative learning rather than via questioning its substantive governance architecture (Allan and Curtis, 2005; Kashyap, 2004; Lankford et al., 2007). Thus even though the moniker 'IWRM' may have lost some of its original authority as the hegemonic model for river basin management, river basin authorities continue to address the complexities of water management at the basin level via a centralised regulatory model regardless of whether the term IWRM or AWRM is employed. For the purposes of this discussion, we have used the term IWRM to mean regulatory integrated water resources management applied to the river basin.

However, this paper is more critical, and is inspired by a key question; do conditions in SSA[1] undermine the rationale for a regulatory integrated approach applied at the basin scale? Conditions such as marked seasonality, large distances, high evaporation losses from irrigated lands, an institutionally challenging environment (Cleaver and Franks, 2005), lack of data monitoring, and little artificial recycling or reticulation of water suggest, in total, a complex and yet relatively under-resourced environment. In other words, basin-wide formal regulatory responses may be too cumbersome to meaningfully address institutionally and geographically remote variety and dynamics. It is this lack of policy fit – rather than its implementation – that might explain why IWRM has not overcome (or perhaps has even led to) inertia in basin management. The paper touches upon other topical issues; the relationship between conflict resolution and river basin management; connections between data, decision aids and river basin management paradigms; and relationships between irrigation infrastructure and basin management.

We believe that a particular problem in IWRM policy is revealed when the idea is applied to African river basins. The problem is that basin officers and consultants adhere too closely to the principles of IWRM when interpreting and initiating the practice of IWRM. Thus, IWRM, which is a theory of planning for the balancing of supply and demand over a large basin by formal regulatory approaches, tends to be interpreted at the practice level as basin operations of the same (see Mitchell, 1990, 2004 for discussions on theory and practice which he termed 'strategic' and 'operational' respectively). The consequences are operations that are excessively comprehensive and too formal to be effectively implemented and for certain African basins may not be sufficiently tailored to circumstances, especially the unpredictable dynamism in water supply and demand found there. Furthermore, because adaptive management refines the practice (operational) level but not the theory, adaptation of IWRM practice cannot generate a categorically different approach. In this paper, we explore whether a genuinely different approach to water resources management (WRM) exists at the higher theory (strategic) level that in turn might spawn an alternative and more appropriate practice/operational model.

We argue the alternative approach is a polycentric model of water resources management applied to the river basin. 'Polycentric' is the term that most appropriately characterises the alternative to IWRM; it denotes the division of the basin into a mosaic of nested subunits rather than integrating it into a hierarchical whole (Ostrom, 2009). In addition, water officers, policy and programmes are obligated to focus on pursuing immediate and customised solutions to problems that subunit societies face including the provision of scientific services to support local policy-making and the fostering of local standard-setting and agreements on monitoring, rewards and penalties. Furthermore polycentric

[1] Although the paper focuses mainly on sub-Saharan Africa, by extension, a polycentric model of river basin management could apply to other environments, for example in Europe.

water resources management encapsulates the co-construction and co-management of appropriate technologies for water distribution and allocation. The emphasis is on subunits that function internally, but also subsequently nest together to give the basin-wide performance sought.

The two water management approaches are captured by the 'Cathedral[2] and the Bazaar' metaphor of Eric Raymond (1999) who contrasted the proprietary computer code written by in-house developers and protected by copyright law (the cathedral) with the decentralised, open-source coding written by many unrelated individuals (the bazaar). We hesitate to suggest that the open-source code enabled by instant access via an intra/internet equates to water which by its very nature is not immediately and simultaneously accessible or knowable by all. Yet, the comparison applies not to the resource/source but to the construction of knowledge and human interaction around it – the metaphor is a powerful abstraction of two paradigms of organisational management. We attach the 'cathedral' term to regulatory water resources management expressed at the basin-wide level and delivered by government or donor-salaried scientists and officials. We use 'bazaar' to describe a polycentric model of water management that focuses on nested zones or catchments within basins where local policy of water management is developed by water users yet supported by a range of tailored governmental and NGO services including the provision of scientific studies. The two models are described in greater detail below.

THE BASIN-WIDE REGULATORY APPROACH (CATHEDRAL)

Regulatory river basin management (IWRM applied to basins) uses statutory control (permits, directives, prohibitions and charges enforced by legal sanctions) of water abstractions and discharges against proprietary or nationally or internationally set standards following due consideration of other water users' needs. Although there are elements of stakeholder participation, IWRM predominantly uses a 'command and control' regulatory regime to manage water demand and maintain the quality and quantity of water supply across a river basin. IWRM requires regulatory organisations to acquire a decision-making process to resolve whether a water transaction can take place, drafting and issuing a legal 'permit' of water use specifying the conditions and 'policing' compliance through monitoring and enforcement. Key features of the IWRM model are a reliance on surveys (see for example, Ramsar utilising Dickens et al., 2004), data, science-based decision support systems and the charging of water users to recover the operational costs of water resource regulation.

Because the aim is to cover quite large river basins as single units (e.g. the Pangani basin in Northern Tanzania) basin management tends towards a hierarchical design. Lower-level user groups are represented in higher groups or within the apex authority. The hierarchy is seen as sensible because water supply or demand in a river basin manifests itself as an additive common resource. The total supply needs to be quantified and added up to be balanced against the total demand, so that excessive demand can be regulated. A central viewpoint is deemed necessary to explore trade-offs between users and suppliers that may be very distant from each other.

An example of these reforms can be found in Tanzania (World Bank, 1996, 2004). The Government of Tanzania and the World Bank saw integrated water management delivered via basin authorities as a fundamental prerequisite to achieving the country's development goals. Institutional reform was based around a new water resource law that is almost a facsimile of that in the UK. Countries in SSA are also exploring IWRM reform in river basin applications; e.g. Zambezi River Authority; Catchment Management Agencies in South Africa; Volta River Authority; Kenya's Water Resource Management Authority; and the Division of Water Resources in Uganda (see Wester et al., 2003; Waalewijn et al., 2005; Ballweber, 2006).

[2] We have employed Raymond's phrase as metaphor for institutional or organisational architecture rather than a comment on religions, Christianity or ecclesiastical buildings. Cathedral is a word with roots in Latin, *cathedra*, meaning 'seat' or 'chair' – signifying throne or authority.

Van Hofwegen and Jaspers (1999) and Jaspers (2003) outline the cathedral IWRM model, listing constitutional changes and providing a list of functionalities that must be in place. A sample of these includes: a decision-making capacity which reflects the interests of different uses and users; a clear regulatory framework with norms and standards; a system that allows analysis of several scenarios for interventions in use of water at basin level; an effective and transparent accountability mechanism; water resources assessment (quality and quantity); demand analysis and demand forecasting; system simulation and optimisation; multi-criteria trade-off analysis; involvement of stakeholders; allocation of water resources; administration of service provision to water institutions; operation and maintenance; monitoring and evaluation; financial management and performance auditing.

Integrated water resources management is perhaps best recognised via its manifestation in now widespread training programmes, for example provided by Global Water Partnership (GWP). Curricula content includes many of the items listed in the previous paragraph. A web search of GWP, World Water Council, UNESCO, Ramsar, IWMI and UNEP provides evidence of policy thinking that mirrors the kinds of approaches found in training courses. IWRM is also evident in the practitioner-to-practitioner capacity-building initiatives held during 2005-2007 between environmental institutions in East and South Africa and the United Kingdom's Environment Agency. Here, predominantly hierarchical models of regulation and enforcement were mapped from the UK to very different contexts found in SSA, although refinements followed when constraints in Kenya demanded a rethink (Hepworth, 2007).

Examining the training and policy tools of IWRM is not simply a device for listing its components. It is germane to the argument that 'cathedral style' IWRM is given significant credibility when and where training is conducted and policy on water resources management is formulated. During water training, a self-referencing edifice of IWRM is provided, explaining science and personnel requirements, core principles, planning modes, structures, linkages, and objectives that need to be put in place. Such training and policy resources appear authoritative and knowledge-based, providing participants with the viewpoint that river basins should be addressed hierarchically and legalistically via a range of 'integrated' activities.

QUESTIONING THE REGULATORY IWRM MODEL

On the basis of emerging literatures and empirical work conducted in Tanzania,[3] we question both IWRM 'theory/strategy' and its 'practice/operation'. We start by asking whether basin officers and water workshop trainees are tasked with distinguishing IWRM theory from operational practice that might allow locally appropriate basin management variations to be drawn up when trainers and advisory documents rarely provide this distinction. It would seem not; for beyond the training classroom, our evidence suggests that officers attempt to implement the substantive regulatory version of IWRM and that the interpreted 'practice' outcome is the result of what is omitted because of limited resources or because participatory procedures deliver user consultation (principally around water rights), rather than a purposive customising of IWRM (Mehari et al., 2009; Lankford et al., 2007).

Basin stakeholders appear not to be asking whether alternative approaches might exist, but asking how to assemble the operational provisions necessary to implement the regulatory model. At a river basin workshop in Nigeria (Lankford, 2005), academics and government-level participants were asked to consider what they could do in the short term to allocate water between urban, agricultural and wetland sectors. Respondents drew up long lists of actions that constituted 'regulatory river basin management' rather than immediate 'make-do' steps to resolve pressing conflicts. When asked at a seminar in London how the Environment Agency would manage a river basin in East Africa that had no monitoring network, the answer given was to set up a monitoring network (Hepworth, 2007). At a

[3] See for example McCartney et al., 2007 and Franks et al., 2004.

World Bank-funded workshop[4] in Tanzania, a senior World Bank water resources specialist insisted and was later repeated by the Ministry of Water's Director of Water Resources, that "water resource management is impossible without data". With such persuasive backing there seems little room for dissent from this kind of IWRM message. This is sensible provided the cost, sustainability and usefulness of such provisions are assured. However, networks for river data collection in Africa are in a poor state (ECA, 2000). So a key entry-point question for our theorisation is; how can a river basin be managed if very little or no data and analysis remain the de facto situation?

In the paper, although we question whether the regulatory centralised model should necessarily be the dominant planning version and whether it functions well in all river basins, we are particularly critical of its application to basins located in SSA. Such basins are generally very large, between 15 to 150 thousand square kilometres and comprising disparate communities, institutions and environments. In SSA, daily evaporation rates of 6-9 millimetres from very large areas of irrigated agriculture compared to evaporation rates of 2-5 millimetres in humid northern Europe frame a markedly more dynamic and less-forgiving 'demand-side' dynamic in semiarid areas. Agro-meteorology and geologies combine to create a strong seasonality of surface water in the savannah plains and watersheds of SSA.

We should recognise the limits of cathedral models adopted from humid/temperate/ oceanic contexts that presuppose both a predictable and less-fluctuating supply and relatively fixed regulated demands arising from mostly industrial and domestic needs. Applying formal water licensing to an environment where water supply and demand fluctuate both intra-seasonally and inter-annually, and where the demand curve is often increasing, is questionable (Lankford and Beale, 2006). In some African basins, changes in demand are further accentuated by rapidly growing urban populations and irrigation so that regulatory suppositions of water demand date quickly. This, plus marked seasonality, may partly explain the mixed record of water rights in Tanzania as a means to adjust demand (van Koppen et al., 2004). This challenge will magnify as basins experience increased variability stemming from climate change (refer to Lankford et al., 2009, for further discussion on the dynamism of this type of environment).

In addition, many African basins' regulatory organisations, logistics and infrastructure for monitoring demand and supply are generally under-resourced. These basins are different from those found in Western Europe that experience wetter temperate/oceanic climates and where authorities have access to considerable financial, human, transport and technological capabilities which allow them to fulfil their duties according to accepted standards and protocols associated with IWRM. Thus while the UK's Environment Agency has approximately 12,000 staff, Kenya's equivalent has less than 100. Yet it is from these well-resourced countries that policy templates and curricula for IWRM are exported.[5] The appropriateness of the regulatory model to poorly resourced river basins is a question that should be studied more deeply (Molle et al., 2010; Carter, 1998; Merrey, 2009) given that implementation of IWRM will be extremely challenging due to a capacity and information vacuum (World Bank, 2005).

Similarly, efforts to replicate a working regulatory regime optimistically assume the prerequisites of a functional and fair judicial system and associated procedural legal capabilities are in place. The practical impossibility of intra-government litigation and political backlashes against enforcement together with procedural defects emasculate regulatory compliance.[6] As the managing director of an openly polluting industry in Tanzania puts it "The biggest problem with water management here is corruption. There is a system but nobody follows it. It is possible to pay off anybody for anything" (Hepworth, 2007). The problems of the regulatory route are evidenced by the 35-year record of Tanzanian water pollution legislation – it has been exercised once with a $30 fine. Whilst tackling

[4] The cost of the workshop was estimated to be the same as the government's entire annual operational allocation to its largest river basin office.

[5] "The Tennessee Valley Authority (TVA) is one of the best known examples of a successful river basin organization" (GWP, 2004).

[6] Field research by Hepworth (2007) reveals that many water pollution cases in Tanzania have never been taken to courts, despite the country having a sophisticated water law for more than 20 years.

corruption forms an ongoing development objective (Blundo and Olivier de Sardan, 2006), its role in undermining regulatory water management is likely to persist at least in the medium term. Therefore, would modalities drawn from community-based reflexive law,[7] or from the evolution of institutional arrangements in the face of formal legislative prosecution (Blomquist and Ostrom, 2008), better address such conditions?

We note occasions when *in practice* IWRM has not been applied as an orthodoxy by experienced water scientists and officers. In some circumstances, particularly over time and with experience gained, non-regulatory pragmatic operational solutions have been deployed by water agencies in the UK and elsewhere in Europe. For example, in a largely regulatory environment, UK basin officers in the Ribble catchment made improvements by reinterpreting regulatory pathways via dialogue with water users (Bond, 2005). Similar examples were found in the Rufiji Basin Water Office in Tanzania where officers opted to engage users in discussion rather than via the courts. In these situations, the objective was not the application of water law per se but helping users become environmentally cognisant by providing advice, recognising logistical, economic and capacity constraints. Prevention of conflict was preferred to prosecution, being less costly for both regulator and user, with legal enforcement only used as a last resort. Within certain constraints (to ensure consistency and credibility of the authority) there was room for the regulatory officers to build relationships with and between water users.

It would seem experienced basin officers know when to shift between cathedral and bazaar modes. We agree this flexibility may be defended as the product of IWRM strategy interpreted into IWRM practice. But two observations are made. First, what should water scientists make of situations where the IWRM regulatory model is consistently and/or thoroughly set to one side in order to deploy it in practice? Does this suggest a starting point that is closer in theoretical design to observed practice? Second, what are river basin officers in SSA to make of donor-funded projects constructed by consultants (e.g. World Bank, 1996) who recommend the application of regulatory procedures upon which further funding is contingent? Therefore, to what extent is the policy of IWRM in developing countries (and generalised further afield) the construct of an industrialised management model imposed by funding conditionalities?

Furthermore, and in the same vein, risk-based approaches have achieved real improvements in water management. The UK's Environment Agency (see EA, 2006) teaches risk-based ideas in its training in Kenya and Tanzania, defined here as the identification of a small number of tasks that unlock success rather than pursuing many activities.[8] While this denotes a pragmatic identification of cost-effective tasks, this nonetheless illuminates the fact that the regulatory framework remains the underlying template for water management. However, discerning observers might note that the risk-based approach could be interpreted as the antithesis of an integrated approach working on many fronts. Clemett et al. (2000), via their major review of water sector programmes, provide evidence of the dangers of 'institutional procrastination' where a focus on long-term structural change or development of comprehensive networks means that urgent operational activities such as the provision of clean water are, or are perceived to be, neglected. Could it be that the more 'integrated' we make IWRM, the more we impede its deployment? As one technician of the Ministry of Water in Tanzania put it: "We always try to do big, big things when what we really need is small, small steps" (Hepworth, 2007).

In summary, although in practice there is considerable scope for the interpretation of IWRM principles, it is rare that the operational version of IWRM effectively and resolutely transcends its higher 'strategic planning' parent and if it does, it appears to be an uneasy arrangement. It is because this potentially flexible theory-practice framework does not deliver sufficiently innovative river basin

[7] Reflexive law describes an array of agreements constituted from within organisations and communities rather than imposed from outside. Reflexive law therefore covers informal customary law, and newly instituted bye-laws (Teubner, 1983).

[8] The Pareto principle is an expression of risk-based thinking, where 80% of consequences are believed to come from 20% of the causes.

management (especially in the context of sub-Saharan Africa) that we take issue with IWRM theory. Transcending this inertia requires a theory that lends itself to local expediency and rapid implementation – the subject of the next section.

A POLYCENTRIC MODEL OF RIVER BASIN MANAGEMENT (BAZAAR)

By comparing with cathedral-style IWRM in table 1, we suggest some preliminary ideas of an alternative bazaar model of polycentric water resources management (PWRM). Here, a theoretically and practically appropriate model rests principally on the identification of subunits of river basins and of the mechanisms and services to support forms of deliberative democracy (Neef, 2009) required for water management within and between these subunits. Table 1 begins by briefly suggesting which types of environments are best suited to either model.

Scale – the creation of nested subunits

The hydrological underpinning of a localised polycentric approach applies to basins amenable to nested, modularised (compartmentalised) solutions by breaking up the larger river basin into building blocks or subunits. The term *holon* may be applied here (Koestler, 1967; Ashby, 2003), which is defined as a component or unit which is simultaneously a whole and a part (see Figure 1). The design decision is to choose holons that constitute significant and useful building blocks of the bigger river basin.[9] Since holons nest in each other (*viz*. farm outlet, tertiary irrigation units, secondary units, irrigation system, sub-catchment, river basin), the holon of interest must neither be too small to result in too many units nor too large or excessively complex so that internal rifts and divisions arise that cannot be managed. This effectively means that zones or units in the basin must be identified wherein water balances and institutional arrangements are *complex enough* to warrant attention by a managerial body that becomes responsible for that subunit. This in turn gives rise to an architecture of subunits where water allocation at the basin scale is the product of water distribution resolved internally within each subunit and water allocation between subunits. The aim is to minimise the transaction costs associated with allocating water between too many individual users across the basin.

The creation of basin subunits, or holons, aims to better accommodate the dynamism found within and across river basins, particularly those in SSA described above. The combination of marked spatial and temporal fluctuations in supply (partly connected to convective rainfall patterns) and non-equilibrium demand suggests that uniform country-wide (because national water law is employed) standards and procedures will lead to deficiencies in policy accuracy and efficacy. Instead, basin subunits offer the opportunity to harness and foster community responsiveness to these localised dynamics – a subject discussed next.

[9] The principle of creating holons to sub-divide a basin need not be limited to developing country or sub-Saharan basins; the aim is to structure a basin that removes or reduces the depth of reach between the apex regulating body and the myriad water users.

Table 1. Comparison of two river basin management approaches.

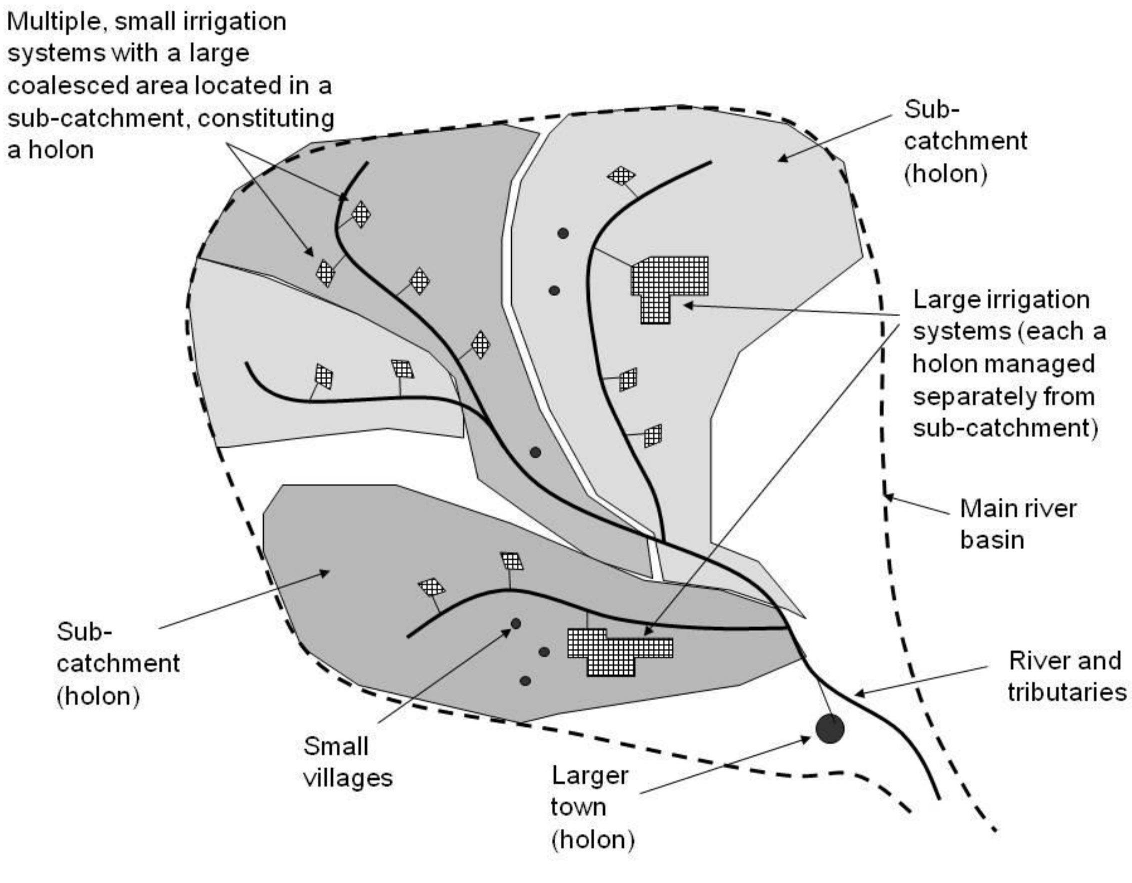
	Regulatory legal authority integrated water resources management (IWRM) **Cathedral**		Polycentric, water resources management (PWRM) **Bazaar**
Conditions best suited for model	Complex systems, mixed multi-sectoral demands, closed basins, mixed quality and quantity issues, high degree of urban, industrial and power needs. Requirement for transfer of water between sectors		Basins that can be modularised or nested and that can be monitored with few monitoring points. Basin allocation solved by addressing local water redistribution
Form/Scale	Hierarchical, vertical, centralised, basin-wide		Distributed, horizontal, modular, decentralised, polycentric, nested comprising units or holons
Dimension	Sub-class	Cathedral	Bazaar
Legislative framework	Water rights and legislation	Formalised, denominated, often fixed. Statutory and nationally ratified	Customary law and reflexive law. Frequently negotiated and adjusted, emphasising transparency and proportionality, and role of informal legal agreements
	Water rights [and obligations]	A right to a volume [To measure water volumetrically]	A right to negotiate [To agree to divisions in water by various ways; time, proportional flow, etc.]
	Enforcement	To legal standards	Informally, to local agreements and bye-laws
	Pollution control	Monitored, standards, regulated.	Nested locally acceptable solutions
Water allocation	River basin visions	Target-led, scenario-based 'A healthy catchment'	Improvement on today's date. Conflict resolution. 'A healthier catchment'
	Water allocation	Via regulatory practice, claim and counter-claim. Inter-sector allocation	Via dialogue and experimental adjustments; incremental. Inter-holon/unit allocation
	Dublin Principles	Widespread acceptance. Seeks equitable water distribution	Locally set priorities, conflict resolution. Seeks a *more* equitable distribution of water
	Hydrological regime	Tends not to differentiate between supply phases	Uses phases of river supply to discern key objectives
	Negotiation, decisions, trades	Regulator-to-user, centre to user, user to centre	User-to-user facilitated by key individuals/personalities
Science	Risk-based approach	Large number or network of features, acts or points, composite, on many fronts	Small number of features or points to lead to outcomes. Immediate, incremental, directly starts to adjust today's practices

	Monitoring of water supply	Formal hydrometric networks, hydraulic formality in gauging	Informal, ad hoc, local knowledge – hydraulic informality in gauging
	Data needs	Substantial and formal – hydrologist defined	Light and informal – locally defined
	Decision tools	Computer decision support system	Informal participatory methods, e.g. gaming,
	Science	Normative, reasoned, central to the model	Post-normal, reflective, in support, secondary
	Scientists	Allied to the river basin authority. Natural scientists converse with social scientists to implement policy	Allied to water users. Scientists as social agents of change. All scientists work together to support users
	Allocation methodology and scale	Demand-derived, reconciled at the basin level	Supply-set and cascaded; reconciled at the locally nested (sub-catchment) level; experimental
	Supply and demand calculations	Formulae, building blocks, professional norms.	Incremental adjustment, locally-measured, local and/or multiple methods
	Quanta and metrics	Quantified, modelled, discharge in litres/second	Verbal, look-and-see, percentages
Institutional strength-ening and design	Subsidiarity	Village and irrigation system water user associations (WUAs)	Multi-layered, irrigation and sub-catchment WUAs
	Participation	Consultative	Substantial (via conflict mediation)
	River basin office	Multi-office in foreground of basin management	Mini-Office; fewer people, providing overview of the river basin
	Entry points	Positions	Interests
	Capacity building	Training and workshops	Mentoring while working
	Role of experts	Experts central and leading	Experts in support, requested
Infra-structure	Water supply provision	Opts for reticulated supply network, large-scale solutions	Aiming for nested solutions, local recycling and storage.
	Distribution infrastructure	Centrally planned, volumetric, formally engineered/constructed	Locally planned and constructed, enhancing access, transparency, flexibility and proportionality

Although subjective, we can explore some sensible ideas of what might constitute holons. Critically, in our view, criteria for nested subunits not only include area but the density or concentration of users competing over a limited resource. Thus, a large, single irrigation system with high levels of internal complexity, measurably affecting its surrounds can be treated as a holon. Areas of coalesced smaller irrigation systems combined with domestic and environmental claims mean that relatively small sub-catchments and aquifers may also be holons. Other examples are: rural towns, or districts of very large towns and cities; irrigation systems approximately 1,000 ha (10 km^2) and above; aquifers approximately 200 to 2,000 km^2 in size; and without being prescriptive, if the river basin area covers 1,500 to 150,000 square kilometres (or more), then polycentric units might comprise possibly from 250 to 20,000 km^2 depending on the size and complexity of the basin and component parts.

Creating holons requires WUAs to own and manage them in order to distribute water to meet internal and downstream needs. Hydrologists and users should also discern whether the basin can be divided into nested manageable units on this basis so that effective user-to-user and user-to-hydrologist negotiation is made possible. Likely to be a difficult and certainly site-specific decision, correct sizing is also served by selecting units that meaningfully 'stretch' or exercise their water users in terms of learning about non-local effects. Thus the boundaries of holons are drawn beyond their comfortable and normal expression – or 'stretched' – so that non-local and scalar expressions of water use can, to some extent, be understood by users who ordinarily would not be faced with the non-local consequences of water depletion. This is important if we are to enhance basin-wide performance by making internal associations and agreements that are also outward-looking.

Figure 1. Schematic of nested holons within a river basin.



The final form of holon architecture is critical to the success of the bazaar approach precisely because it aims to design in subsidiarity and determines the nature of water allocation within the basin. Water governance and authority are distributed to each holon with the principal aim of improving water distribution within holons. This leaves water allocation between holons rather than between sectors as the duty of a basin-wide office. While both cathedral and bazaar modes require a basin-wide perspective on allocation performance, the contrast between the two models could not be clearer: the cathedral seeks a comprehensive regulation of many individual water users (recognising their sectoral provenance) that merits additional vertical authority and a reliance on data collection and analysis for it to function. The bazaar aims to foster self-regulation of water abstraction by holons in order to promote allocation between holons. Furthermore, since a holon may encompass different sectors (e.g. a wetland and an irrigation system), novel opportunities to meet inter-sectoral allocation challenges are provided.

Socialised services for deliberative democracy

If appropriate management subunits or holons can be formed, we then need to ask how they can be governed and administered. In this section, we explore a set of key ideas that together represent a relatively high degree of sophistication in terms of services provided by governmental, science and non-governmental bodies and organisations (table 1 gives a range of issues to be reflected upon in terms of how the science of river basin management is delivered to local users). The ideas presented here attempt to sketch out an intensity of service provision that meets the concerns voiced by Neef (2009) of the potential limitations of participatory natural resource co-management. Pragmatically, the aim of such services should not be the solving of all problems of water allocation but rather the tackling of the worst problems that might occur under a poorly constructed and resourced cathedral style model applied to inappropriate circumstances.

There is evidence from education, health programs and water and sanitation that citizens' action and participation combined with appropriate service responsiveness can generate the requisite levels of system performance (Cavill and Sohail, 2004). This has been explored within a participatory governance and accountability framework (ibid), and has been termed a Demand-Responsive Approach (World Bank, 1998). The approach brings water users into a process of selecting, implementing, auditing and, ultimately, financing the long-term delivery of water services.

Major proponents of the approach, including the World Bank, have supported its uptake. Initiated by WaterAid, the aim of Citizens Action for Water and Sanitation (Ryan, 2006) was to support programmes to strengthen governments' accountability in service delivery. The programme put communities in charge of their own problems and solutions, utilising open consultation processes, community scorecards, slum censuses and mapping of water and sanitation amenities.

Experiences in Tanzania (Van Koppen et al., 2004; Sokile et al., 2005; Mehari et al., 2009) suggest that it is more reasonable and effective to entrust management of water to sub-catchment decision-making building on already existing customary arrangements. Their tasks would be, first, regulating allocation in times of low flows, with constraints on abstraction to ensure downstream flow as advised by Basin Officers and, second, finding arrangements for dealing with the increasing demands by new users. With the right approach and institutional environment there is no reason why communities should not be able to recognise wider impacts of their water usage and connect productivity gains to conflict resolution both at catchment and irrigation system levels (McCartney et al., 2007).

An increasingly significant debate examines how to increase the accountability, accessibility, accuracy, applicability, affordability and response times of services for the purpose of improving natural resource management (IIED, 2006). This also means engaging and empowering water resource users to demand or purchase services, and to do so in a way that first asks users to critically prioritise solutions to identified problems so that services meet real gaps and not those that can be solved relatively easily by resource users themselves. This suggests a recursive relationship between users and service providers, with the latter fostering the ability of the former to come to them and vice versa. The ability of productive irrigators to fund service provision would be key in the sustainability and appropriateness of services provided and may not be too difficult; 1% of the turnover of 1,000 hectares of irrigated rice in Tanzania is US$10,000 which could buy services related to mapping, conflict resolution, legal settlement, field trips, redesign, construction, accountancy, climate forecasting and so on.

In addition, the provision of pluralist legal frameworks is a diagnostic part of a socialised servicing of polycentric governance in that holons may draw up their own distinctive bye-laws to meet internal and external water distribution obligations. Thus in the cathedral model, one water law applies to all parts and levels of a river basin, while in the bazaar, a variety of water agreements are at work across horizontal and vertical scales. A locally nested framework implies that formal regulatory systems need to be counterbalanced with mixtures of formal and customary law, where formal statute law provides a broad framework that defines 'equity' in the legal sense, and where customary and reflexive law (Teubner, 1983) resides at the catchment, irrigation and community level to draw up agreements and protocols that bring about equity in a tangible, hydraulic sense. Should customary agreements not provide resolution, users could then solicit or purchase legal services to resolve disputes.

Service providers would be encouraged to promote risk-based approaches and identify tailored solutions that generate the most effective or rapid outcomes and rewards. In addition, work scheduling defines the pace at which basin management is pursued. Watkins (1998) and Moore (2004) identify the setting of deadlines to force action in this respect. Thus, a decentralised PWRM approach is defined by, and insists on, 'quick progress' in basin management. This may be possible because of a relatively straightforward challenge of quantitative allocation perhaps underpinned by a small number of critical monitoring and flow-adjusting points in the basin that, in turn, by devolving action to water users need not be formally engineered.

DISCUSSION – EXPLORING THE TWO APPROACHES

Differences in interpretation of the WRM theory are drawn from case material in Tanzania and Nigeria. While the World Bank-funded programme River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP; World Bank, 1996) drew up a regulatory approach to cover all water users in the Upper Great Ruaha Basin, the key water allocation conflict in the area could have been addressed by simpler means. We observed that the irrigation sector is upstream of environmental and hydropower needs and that a handful of irrigation intakes on four perennially flowing sub-catchments significantly influenced water apportionment (see Lankford, 2001). While the RBMSIIP attempted to regulate demand via the charging of water through the selling of water rights,[10] a village in the Mkoji sub-catchment implemented its own policy for dampening water demand by initiating a levy (approximately 1 dollar per acre) for land prepared for rice irrigation – recognising that area is easier to measure than water flow.

Regarding risk-based approaches, while scientists at a workshop in northern Nigeria argued for a network of standard gauging stations (that would then require formal data collection and use), it was possible to identify a few existing points in the basin that could be gauged using informal methods, including the bough of a landmark large tree and a bridge culvert. The choice here is pragmatically informed by work scheduling, scale and risk; how to make progress in water management tomorrow – not an abstract 'tomorrow' – by using local and existing knowledge and infrastructure that meet both local and wider needs. If decisions to act are framed by reference either to nationally determined standards and procedures of IWRM (cathedral) or to local problem-determination (bazaar), we believe the latter would engender greater efficacy.

[10] Many of the articles in the reference list that discuss river basin management in Tanzania (e.g. Lankford et al., 2009) explain the technical errors of this policy.

The cathedral, regulatory model derives further legitimacy from its use of science – for example intra-sector algorithms to compute demand quotas. One example is the derivation of crop water requirements and irrigation demand that now looks to be outmoded in this respect (Lankford, 2004a). Scientific methods to determine environmental flow assessment (King and Louw, 1998; Pyrce, 2004) appropriate for computational claims on water have to be similarly questioned because it is possible, more pragmatically, to reset tomorrow's supply quotas by a percentage adjustment of today's supply[11] or by experimentation (Vounaki and Lankford, 2009).

Conflict resolution should be seen as a defining feature of decentralised basin management because it strongly features local problem resolution via incremental dialogue-based steps rather than by initiating solutions underpinned by official protocols for determining water demand. The experience of the authors in gaming as a form of conflict resolution is instructive. Lankford et al. (2004) used the River Basin Game to see that adjustments of existing shares is a feasible way of progressing in comparison to water demand claims based on computations as found in an allocation model. One example of the incremental approach in Tanzania occurred in the Mkoji sub-catchment where day schedules were applied and adjusted to provide water to different irrigation intakes (Rajabu, 2007). Conditional agreements between parties, though perhaps not legally recognised, could refer to customary practices, or be instituted as local bye-laws and other forms of reflexive law.

The role of the advisory expert is different in the two models. In the regulatory model, the advisory professional manages the regulation of water and dictates the standards that must be met. As Raymond found, the cathedral emphasises products generated by specialised experts who consequently take a leading role in formulating and owning knowledge that is then, via consultation or the market, handed over or sold to users. In river management, examples of products are pollution standards, water rights, computer decision-aids, highly engineered intakes and legalised claims for water. In the bazaar, professionals do not work without recourse to scientific methods and protocols but do so in a process mode; i.e. by allowing knowledge to be requested and framed by water users so that products are produced and owned by them. In the bazaar, resource users seek solutions that fit their particular locality and stage of understanding or concern asking for conflicts to be mediated while recognising or being reminded of wider basin obligations. Examples are mapping services, conflict-resolution workshops, irrigation infrastructure retuning and legal advice. Communication from resource users to a much more responsive basin office is cultivated.

With further reference to risk-based approaches, we found that in southern Tanzania, the key water allocation period was principally during the drier eight months of the year outside of the main wet season (when rivers and rain combine to meet most water demands of all sectors); and that, but for all of four rivers, the smaller sub-catchments were seasonal and thus mostly without water. Thus it becomes expedient to determine the allocation needs for particular rivers at different times of the year. In this way, dissecting the hydrological regime into three phases or states of water supply allows the categorisation of key objectives within each phase. These phases are; 1) 'critical water' denoting very small amounts of water availability during droughts and the dry season; 2) 'medial water' for scarce-to-average flow conditions, and 3) 'bulk water' for wet-to-flood conditions (see Lankford and Beale, 2006; Lankford et al., 2007). This allows the allocation aims and devices (markets, command and control, local community responses and other interventions) appropriate for each phase to be drawn up. A look at the Tanzania case study indicates that critical and medial water requires special attention by the basin office, but that each could be addressed by relatively simple, practical and localised solutions rather

[11] The UK government part decides an allocation of funds to universities using 'annual efficiency gains' of 1-2% and not computations of where and how that money is utilised within universities (Greenaway and Haynes, 2000). This demonstrates the differences between demand-side 'building block' calculations of demand and supply-side forcing of reduced demand. At a recent workshop in South Africa, one author of this paper was told of commercial farmers in the Olifants basin recently agreeing to a decrease in allocation in order to provide water to smallholders, breaking a deadlock in negotiations.

than by more cumbersome formal rights-based interventions formulated to work for all river-flow discharges.

The type, application and ownership of basin water technology define the differences between the two models of basin management. In Tanzania, for example, donor programmes utilised a high level of engineering formality in designing basin and irrigation infrastructure (see Lankford, 2004b for more information). In contrast to this, also in Tanzania and in Nigeria, local users and projects have explored technical designs that employ materials such as stone gabions, log-stops and metal shutters that tend to result in proportional division rather than undershot orifice gates favoured by engineers. At a deeper level, these bazaar technologies create a platform for giving local users ownership, access and permission to constantly retune and adjust infrastructure to meet the pace of change in their sub-catchment, and to ensure acceptable levels of transparency in water division and allocation. The choice of technology – formal or informal – fits the degree of pragmatism required within the locality of that nested part of the wider basin. The reader is referred to Lankford and Mwaruvanda, 2007 for a discussion on appropriate proportional structures that support frequent and nested adjustments of water allocation, improving knowledge of water distribution without recourse to flow measurements.

In summary, we argue that the components of each side of table 1 work in unison to define categorically different approaches. Current regulatory river management is constituted from an interlinking of formal and normative building blocks applicable to a hierarchical, centralised regulatory approach with basin-wide jurisdiction. An alternative is made possible by sub-basin differentiation, composed of systems of polycentrism, subsidiarity, informality, pragmatism, incrementalism, appropriate technology, problem-solving and peer-to-peer dialogue facilitated by water officers, legal experts, hydrologists, scientists and other service providers. The cathedral and bazaar metaphor captures this contrast well.

WHAT HOPES FOR POLYCENTRIC RIVER BASIN MANAGEMENT?

Rather pessimistically, for eight reasons we do not foresee that polycentric basin management will be the subject of funded technical programmes for the near future even though polycentrism is gaining acceptability (Molle et al., 2007; Pahl-Wostl and Sendzimir, 2005). First, such scepticism arises because water is seen as multifunctional and integrating, requiring an 'integrated' response at the basin level. The planning of IWRM, manifest in training sessions and workshops, exemplifies this. Few seem willing to interpret river basin management as an endeavour that can be disintegrated, where the science of hydrology and water quality management is locally framed rather than by resorting to national or international standards and protocols.

The second reason is that scale is invoked as a defence; that large river basins necessarily need centralised control and regulation, and that WUAs have limited reach and cannot extend over a great area. Just as open source computing is overseen by a central administrator, we agree and foresee that basin-wide perspectives are needed for the bazaar to function, analysing whether basins can be subdivided into modular units that self-regulate and be reconstituted into a federalised basin. 'Foregrounding' or 'backgrounding' this overseeing authority would relate to the basin model being pursued – in other words, it is a question of where and how authority is located – centrally at the basin level or locally with users.

Third, many water scientists may simply argue that the stakes are too high not to introduce a regulatory model – but that more time, finance and training are needed. With respect to Tanzania, the means to answer this concern have been provided. Over the next decade, the development community will have the opportunity to monitor the impact of another tranche of funding on the performance of IWRM in the country. A sizeable budget of $75 million is funding the next phase of the Water Resources Sector Strategy (World Bank, 2007).

Fourth, even if it could be shown that a pragmatic polycentric model complements an eventual move towards formal procedures, many scientists may argue that it is already captured in the participative dimension of regulatory water management. To answer this requires further exploration of how meaningful subsidiarity goes beyond current practices of 'participation' to solve power or water allocation imbalances. The bazaar does not envisage the absence of courts and laws, but does emphasise local informal and reflexive legal institutions and norms, and the situating of science and scientists at the local user level, rather than within the river basin authority.

Fifth, a theory-practice 'get-out clause' can be invoked; it could be argued that bazaar-type approaches are simply operational interpretations of IWRM cathedrals – the latter being appropriate for higher level or national IWRM. While this may be true, there is a substantive responsibility on those who promulgate cathedral IWRM teaching to either show how IWRM will work in all circumstances or provide bazaar methodologies and interpretations during training sessions and policy work. Currently, the cathedral is emphasised to the detriment of the bazaar.

Sixth, the decentralised approach implies a radically different 'capacity-building' pedagogy. Teaching 'process skills' operable at the local scale is much more difficult and might not be addressed by adjustments to existing courses, i.e. by introducing more role-playing or specific exercises. The polycentric model would require the formulation of a training 'package' comparable to that which exists for IWRM – yet as one Environment Agency scientist said in 2006 at a meeting in which the cathedral and bazaar idea was proposed, 'how could this be done?' For polycentric water management, workshop-based training[12] might be balanced by an emphasis on professional mentoring, implying a different aid model of long-term in situ technical assistance by scientists, NGOs and other support agencies.

Seventh, much scientific inspiration is drawn from examples of the cathedral form in contrast to a deficit of experiences of, and insights drawn from, the bazaar model. Knowledge-sharing between basin officers and supporting scientists at national and international workshops and conferences frequently describes case studies drawn from complex basin environments such as those found in the Danube, Murray-Darling, Ebro and Seine. These basins, some falling within the Water Framework Directive, sensibly chose to tackle scale, allocation, water quality and habitat issues via the cathedral model. Yet we should be critical – the appearance of basins as large and complex need not automatically lead to the accretion of scientific expertise, authority and regulation into a single river agency.

A final reason would be the political blocks in the process of adoption of different models of IWRM – a decentralised model greatly increases the independence of basin officers from national policy – in contrast to the state sovereignty and command and control embedded in the regulatory model. Parallel with this is an increased responsibility on local users to call in services from providers which in turn directs the latter’s accountability downwards to users rather upwards to their higher-level managers.

CONCLUSIONS

River basin strategies and their operation in the future will be a balance between the cathedral and bazaar models. In some river basins, there will be a clear case for a well-financed regulatory authority deploying centrally planned infrastructure, water quality and quantity measurement, and legal safeguards against powerful sectoral interests. In other basins, a basin-centred office might be omitted or be comparatively small, providing essential water resources assessment and monitoring functions, while greater support is provided for the management of localised modular subunits/holons each determining priorities to meet particular internal and external objectives.

However, the explorations of the limits of regulatory water management in the UK, Kenya and Tanzania by the Environment Agency are illuminating; discussions with basin officers as a part of this research indicate that these explorations have not knocked the certitude that regulatory 'command and control' applied to the basin scale is necessary. Although we hold an open mind regarding that we take

[12] A move away from the workshop culture, easily recognisable in the majority of development cooperation programmes in sub-Saharan Africa, may be unpalatable to various parties (Smith, 2003; Policy Forum, 2009).

issue with the extent to which the principles of ex cathedra basin-wide regulation are applied. In this regard, one could empirically argue for polycentric possibilities; such is the large number of institutional and infrastructural options available to fit the wide range of basin conditions observed, it is remarkable that the cathedral format should so monopolise policy and planning. We argue for much greater circumspection regarding a basin-wide regulatory model, and that water managers are referred to a decentralised theory of water management that generates locally relevant, practical operations.

Critically, is PWRM a genuinely different model than IWRM for global interpretation and adoption, rather than solely a pragmatic solution for sub-Saharan Africa (and similar) contexts? In other words, could it be applied successfully in developed humid/temperate countries? While we suspect PWRM is an alternative theory to IWRM, a more thorough answer to this will come from future explorations of PWRM in both industrialised and industrialising nations. By starting with the principles of polycentric local basin management combined in the right-hand side of table 1, we envisage, over time, novel operational derivations of polycentric water resources management that may achieve real progress with the sharing of water. The ontological validity of PWRM will not be found in table 1; instead, it will be garnered in tests of its future strategic interpretation and operational practice.

It is worth returning to the subject of knowledge frameworks that currently wrap around the policy and training of IWRM. As mentioned above, we believe that a considerable self-referencing system of literature, training, workshops and consultancy heavily skews the balance towards the regulatory model regardless of circumstances (for similar points see also Molle, 2008). Little about the use of informal field methods and observations, the role of individual personalities, personal experience, step-wise progress, practical confidence-building and conflict resolution is taught in formal water training. This imbalance means planning and operational designs of IWRM are less open to the possibility that progress can be made by starting with a decentralised, modular, informal mode, on to which more formality and federalisation may be piggybacked in the future. At the very least training workshops might give basin stakeholders permission to start with the bazaar and then move to the cathedral, or indeed to metamorphose half-stalled cathedrals into active bazaars.

Although we are pessimistic about the prospects for polycentric water resources management, we believe the best chance for its implementation will come from politicised/radical water scientists who have – by definition – four traits: sufficient experience and practice to see that cathedral models do not fit all circumstances; the skills and inclination to work with individuals and communities so they are drawn into supporting their experimentations with water; a 'post-normal science' (Funtowicz and Ravetz, 1993) comfort with uncertainty and lack of data; and the confidence to advocate changes in policy to both fellow scientists and upwards to donors and governments. Answering Molle's call (2009b) to re-politicise water policy, we suggest more is needed than to recognise the political nature of river basin management – it is a question of how? In keeping with Jasanoff (2004), if normal science buttresses the hegemonic IWRM cathedral, and community-deliberated post-normal science inspirits the PWRM bazaar, then the revolution starts with water scientists.

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REFERENCES

Allan, C. and Curtis, A. 2005. Nipped in the bud: Why regional scale adaptive management is not blooming. *Environmental Management* 36(3): 414-425.

Ashby, J. 2003. Introduction: Uniting science and participation in the process of innovation-research for development. In Pound, B.; Snapp, S.; McDougall, C. and Braun, A. (Eds), *Managing natural resources for sustainable livelihoods: Uniting science and participation*, pp. 1-19. London: Earthscan.

Ballweber, J.A. 2006. A comparison of IWRM frameworks: The United States and South Africa. *Journal of Contemporary Water Research & Education* 135: 74-79.

Biswas, A.K. 2004. Integrated water resources management: A reassessment. *Water International* 29(2): 248-256.

Blomquist, W. and Ostrom, E. 2008. Deliberation, learning, and institutional change: The evolution of institutions in judicial settings. *Constitutional Political Economy* 19(3): 180-202.

Blundo, G. and Olivier de Sardan, J.-P. 2006. *Everyday corruption and the state: Citizens and public officials in Africa*. London: Zed Books.

Bond, D. 2005. Ribble Pilot-Lessons learned from the UK. In Lawson, J. (Ed), *River basin management: Progress towards implementation of the European Framework*, pp. 87-93. London: Institute of Civil Engineers.

Bonn Secretariat. 2001. *International Conference on Freshwater 3-7 December 2001*. Bonn, Germany: The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; the Federal Ministry for Economic Co-operation and Development. www.water-2001.de

CAIWA (Conference on Adaptive and Integrated Water Management). 2007. 1st International conference on adaptive & integrated water management: Coping with complexity and uncertainty, Basel, Switzerland, 12-15 November 2007. www.usf.uos.de/projects/caiwa/index.htm. Proceedings published as a book: Pahl-Wostl, C.; Kabat, P. and Möltgen, J. (Eds). 2007. *Adaptive and integrated water management. Coping with complexity and uncertainty*. Heidelberg, Germany: Springer Verlag.

Carter, R.C. 1998. Prospects for sustainable water management policy in Sub-Saharan Africa, with special reference to the northeast arid zone of Nigeria. In Vajpeyi, D.K. (Ed), *Water resource management: A comparative perspective*, pp. 107-127. New York: Praeger.

Cavill, S. and Sohail, M. 2004. Strengthening accountability for urban services. *Environment and Urbanization* 16(1): 155-170.

Cleaver, F. and Franks, T. 2005. *How institutions elude design: River basin management and sustainable livelihoods*. BCID Research Paper No. 12. Bradford, UK: Bradford Centre for International Development, University of Bradford.

Clemett, A.; Sonson, J. and Mitchell, G. 2000. Making integrated water resource management work: Lessons from the evaluation of water sector programmes. Working Document. Leeds, UK: University of Leeds.

Dickens, C.; Kotze, D.; Mashigo, S.; MacKay, H. and Graham, M. 2004. *Guidelines for integrating the protection, conservation and management of wetlands into catchment management planning.* Water Research Commission Report Number TT220/03. Pretoria, South Africa: Water Research Commission.

EA (Environment Agency). 2006. Modernising the way we regulate: Position Statement, Environment Agency. www.environment-agency.gov.uk/aboutus/ (accessed 2 August 2006)

EC (European Commission). 1998. *Guidelines for water resources development co-operation. Towards sustainable water resources management, a strategic approach.* Brussels, Belgium: European Commission.

ECA (Economic Commission for Africa). 2000. *Transboundary river/lake basin water development in Africa: Prospects, problems, and achievements.* Addis Ababa, Ethiopia: United Nations Economic Commission for Africa.

EU (European Union). 2005. The EU Water Initiative Website. www.euwi.net/policy (accessed 3 May 2009)

Franks, T.; Lankford, B.A. and Mdemu, M. 2004. Managing water amongst competing uses: The Usangu wetland in Tanzania. *Irrigation and Drainage* 53(3): 1-10.

Funtowicz, S.O. and Ravetz, J.R. 1993. Science for the post-normal age. *Futures* 25(7): 739-755.

Greenaway, D. and Haynes, M. 2000. Funding universities to meet national and international challenges. Mimeo. Nottingham, UK: University of Nottingham.

GWP (Global Water Partnership). 2000. *Integrated water resources management*. GWP Technical Committee Background Paper No. 4. Stockholm, Sweden: Global Water Partnership.

GWP. 2004. *Catalysing change: A handbook for developing integrated water resources management (IWRM) and water efficiency strategies.* Stockholm, Sweden: Global Water Partnership.

GWP. 2006. *Thematic document. Framework Theme 2. Integrated Water Resources Management*. Prepared by the GWP for the Fourth World Water Forum, Mexico City, March 2006. Stockholm, Sweden: The Global Water Partnership.

Hepworth, N. 2007. Elucidating the role of regulatory personality for sustainable water resource management. Report on PhD fieldwork, progress and methodology. Norwich, UK: University of East Anglia. (Unpublished).

IIED (International Institute for Environment and Development). 2006. *Making decentralisation work for sustainable natural resource management in the Sahel: Lessons from a programme of action-research, policy debate and citizen empowerment.* London, UK: International Institute for Environment and Development.

Jasanoff, S. (Ed). 2004. *States of knowledge: The co-production of science and social order*. London, UK: Routledge.

Jaspers, F.G.W. 2003. Institutional arrangements for integrated river basin management. *Water Policy* 5(1): 77-90.

Jones, J. and van der Walt, I. 2004. Challenges for water sustainability in Africa. *Geojournal* 61(3): 105-109.

Kabudi, P.J. 2005. Challenges of legislating for water utilisation in rural Tanzania: Drafting new laws. Paper presented at the International Workshop on African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, Johannesburg, South Africa, 26-28 January 2005.

Kashyap, A. 2004. Water governance: Learning by developing adaptive capacity to incorporate climate variability and change. *Water Science Technology* 49(7): 141-6.

King, J. and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using building block methodology. *Aquatic Ecosystems Health and Management* 1(2): 109-124.

Koestler, A. 1967. *The ghost in the machine*. 1990 reprint edition. London, UK: Penguin Group.

Lankford, B.A. 2001. Red routes on blue rivers: Strategic water management for the Ruaha river basin, Tanzania. *Water Resources Development* 17(3): 427-444.

Lankford, B.A. 2004a. Resource-centred thinking in river basins: Should we revoke the crop water approach to irrigation planning? *Agricultural Water Management* 68(1): 33-46.

Lankford, B.A. 2004b. Irrigation improvement projects in Tanzania; scale impacts and policy implications. *Water Policy* 6(2): 89-102.

Lankford, B.A. 2005. *Facilitation of water sharing arrangements in the Hadejia Jama'are Komadugu Yobe basin (HJKYB) – with the River Basin Game Dialogue Tool.* Final report. Dutse, Nigeria: DFID, Joint Wetlands Livelihoods Project.

Lankford, B.A. and Beale, T. 2006. Equilibrium and non-equilibrium theories of sustainable water resources management: Dynamic river basin and irrigation behaviour in Tanzania. *Global Environmental Change* 17(2): 168-180.

Lankford, B.A. and Mwaruvanda, W. 2007. Legal infrastructure framework for catchment apportionment. In Van Koppen, B.; Butterworth, J. and Juma, I. (Eds), *Community-based water law and water resource management reform in developing countries*, pp. 228-247. Wallingford, UK: CABI Publishing.

Lankford, B.A.; Merrey, D.; Cour, J. and Hepworth, N. 2007. *From integrated to expedient: An adaptive framework for river basin management in developing countries*. Research Report No. 110. Colombo, Sri Lanka: International Water Management Institute.

Lankford, B.A.; Sokile, C.; Yawson, D. and Lévite, L. 2004. *The river basin game: A water dialogue tool*. Working Paper No. 75. Colombo, Sri Lanka: International Water Management Institute.

Lankford, B.A.; Tumbo, S. and Rajabu, K. 2009. Water competition, variability and river basin governance: A critical analysis of the Great Ruaha river, Tanzania. In Molle, F. and Wester, P. (Eds), *River basin development in perspective,* pp. 171-195. Wallingford, UK: CABI Publishing.

McCartney, M.P.; Lankford, B.A. and Mahoo, H.F. 2007. *Agricultural water management in a water stressed catchment: Lessons from the RIPARWIN project.* Research Report No. 16. Colombo, Sri Lanka: International Water Management Institute.

Mehari, A.; Van Koppen, B.; McCartney, M. and Lankford, B.A. 2009. Unchartered innovation? Local reforms of national formal water management in the Mkoji sub-catchment, Tanzania. *Physics and Chemistry of the Earth* 34(4-5): 299-308.

Merrey, J.D. 2009. African models for transnational river basin organisations in Africa: An unexplored dimension. *Water Alternatives* 2(2): 183-204.

Mitchell, B. 1990. *Integrated water management: International experiences and perspectives*. London, UK: Belhaven Press.

Mitchell, B. 2004. Discussion note: Comments by Bruce Mitchell on Water Forum contribution "Integrated Water Resources Management: A Reassessment" by Asit K Biswas: *Water International* 29(3): 398-405.

Molle, F. 2008. Nirvana concepts, storylines and policy models: Insights from the water sector. *Water Alternatives* 1(1): 131-156.

Molle, F. 2009a. River-basin planning and management: The social life of a concept. *Geoforum* 40(3): 484-494.

Molle, F. 2009b. Water, politics and river basin governance: Repoliticizing approaches to river basin management. *Water International* 34(1): 62-70.

Molle, F.; Wester, P. and Hirsch, P. 2007. River basin development and management. In Molden, D. (Ed), *Water for food, water for life: A comprehensive assessment of water management in agriculture*, pp. 585-625. London, UK: Earthscan and Colombo, Sri Lanka: International Water Management Institute.

Molle, F.; Wester, P. and Hirsch P. 2010. River basin closure: Processes, implications and responses. *Agricultural Water Management* 97(2010): 569-577.

Moore, D.A. 2004. The unexpected benefits of final deadlines in negotiation. *Journal of Experimental Social Psychology* 40(1): 121-127.

Neef, A. 2009. Transforming rural water governance: Towards deliberative and polycentric models? *Water Alternatives* 2(1): 180-200.

Ostrom, E. 2009. *A polycentric approach for coping with climate change*. Policy Research Working Paper No. 5095. Background Paper to the 2010 World Development Report. Washington, DC, USA: The World Bank, Development Economics, Office of the Senior Vice President and Chief Economist.

Pahl-Wöstl, C. and Sendzimir, J. 2005. *The relationship between IWRM and adaptive management*. NeWater Report Series No. 3, NeWater project. Osnabrueck, Germany: University of Osnabrueck. www.newater.info

Pitman, G.K. 2002. *Bridging troubled waters: Assessing the World Bank water resources strategy.* Washington, DC, USA: The World Bank, Operations Evaluation Department.

Policy Forum. 2009. Reforming allowances: A win-win approach to improved service delivery, higher salaries for civil servants and saving money. Policy Brief No. 9.09. Dar es Salaam, Tanzania: Policy Forum.

Pryce, R.S. 2004. *Hydrological low flow indices and their uses*. WSC Report No. 04-2004. Peterborough, Canada: Watershed Science Centre.

Rajabu, K.R.M. 2007. Use and impacts of the river basin game in implementing integrated water resources management in Mkoji sub-catchment in Tanzania. *Agricultural Water Management* 94(1-3): 63-72.

Raymond, E. 1999. *The cathedral and the bazaar*. Cambridge, USA: O'Reilly Media.

Ryan, P. 2006. Citizen's action for water and sanitation. Discussion Paper. London, UK: WaterAid.

Shah, T.; Makin, I. and Sakthivadivel, R. 2005. Limits to leapfrogging: Issues in transposing successful river basin management institutions in the developing world. In Svendsen, M. (Ed), *Irrigation and river basin management: Options for governance and institutions* pp. 31-49. Wallingford, UK: CABI Publishing and Colombo, Sri Lanka: International Water Management Institute.

Smith, D.J. 2003. Patronage, per diems and the "workshop mentality": The practice of family planning programs in Southeastern Nigeria. *World Development* 31(4): 703-15.

Sokile, C.S.; Mwarunvanda, W. and van Koppen, B. 2005. Integrated water resource management in Tanzania: Interface between formal and informal institutions. Paper presented at the International Workshop on African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa, Johannesburg, South Africa, 26-28 January 2005.

Teubner, G. 1983. Substantive and reflexive elements in modern law. *Law & Society Review* 17(2): 239-285.

Van Hofwegen, P.J.M. and Jaspers, F.G.W. 1999. *Analytical framework for integrated water resources management: Guidelines for assessment of institutional frameworks.* IHE Monographs. London. UK: Taylor and Francis.

Van Koppen, B.; Sokile, C.; Hatibu, N.; Lankford, B.A.; Mahoo, H. and Yanda, P.Z. 2004. *Formal water rights in Tanzania: Deepening the dichotomy?* Working Paper No. 71. Colombo, Sri Lanka: International Water Management Institute.

Vounaki, T. and Lankford, B.A. 2009. *Feasibility of a legal-infrastructural framework; Insights for the dry season from the Mkoji-Sub Catchment, Tanzania.* A 2006 Fieldwork Report for the RIPARWIN project, reproduced as a Working Paper for the School of International Development. Working Paper No. 20. Norwich, UK: University of East Anglia.

Waalewijn, P.; Wester, P. and van Straaten, K. 2005. Transforming river basin management in South Africa: Lessons from the lower Komati river. *Water International* 30(2): 184-196.

Warner, J.; Wester, P. and Bolding, A. 2008. Going with the flow: River basins as the natural units for water management? *Water Policy* 10(S2): 121-138.

Watkins, M. 1998. Building momentum in negotiations: Time-related costs and action-forcing events. *Negotiation Journal* 14(3): 241-256.

Wester, P.; Merrey, D.J. and De Lange, M. 2003. Boundaries of consent: Stakeholder representation in river basin management in Mexico and South Africa. *World Development* 31(5): 797-812.

Wester, P.; Hoogesteger, J. and Vincent, L. 2009. Local IWRM organisations for groundwater regulation: The experiences of the aquifer management councils (COTAS) in Guanajuato, Mexico. *Natural Resources Forum* 33(1): 29-38.

World Bank. 1996. River basin management and smallholder irrigation improvement project (RBMSIIP). Staff appraisal report. Washington, DC, USA: World Bank.

World Bank. 1998. *Demand responsive approaches to community water supply: Moving from policy to practice, East and Southern Africa*. Washington, DC, USA: World Bank.

World Bank. 2004. *Water resources sector strategy, strategic directions for World Bank engagement.* Washington, DC, USA: World Bank.

World Bank. 2005. Draft Tanzania water resource assistance strategy. March 9, 2005. Presented to East African Integrated River Basin Conference, Morogoro, Tanzania.

World Bank. 2007. *Water sector support project appraisal document on proposed credit to the United Republic of Tanzania.* Report No. 37385-TZ. Washington, DC, USA: World Bank, Tanzania and Uganda Country Department, Africa Regional Office.